Appendix 6

Development and Analysis of Target Fish Community Models to Evaluate the Status of the Existing Fish Communities in the Upper and Lower Souhegan River, New Hampshire

Introduction

The Northeast Instream Habitat Program (NEIHP) at the University of Massachusetts conducted an analysis of fish habitat in the Souhegan River in an effort to identify and define the flow dependency of the native fish fauna within the Souhegan River. This analysis entailed assessing changes in fish habitat availability at various stream flows, and using multivariate statistics to determine which physical habitat characteristics are most suitable for individual or species (or species groups) of fishes. Once these relationships were established, a habitat simulation model (MesoHABSIM) was used to determine the relationships between instream flow conditions, physical habitat, and the fish community within the river (Parasiewicz, 2001). An approach, known as Target Fish Community modeling (Bain and Meixler, 2000), was used to identify the native fluvial species that were considered in the MesoHABSIM modeling process, evaluated the condition of the existing fish community within the Souhegan River, and guided potential habitat rehabilitation measures and instream flow regulation recommendations. We created Target Fish Communities (TFC) for the upper and lower Souhegan River using the method developed by Bain and Meixler (2000) on the Quinebaug River in Connecticut and Massachusetts.

Developing a TFC model consisted of multiple steps. First, a list of species expected or with the potential to occur within the project river was compiled. Next, a group of rivers, physically and zoo-geographically similar to the investigated river and relatively un-impacted, were chosen as references. Fish collection data was then gathered from these reference rivers and used in the calculation of the TFC model. Then, a weighted ranking procedure was applied to these data sets to determine the species composition and relative abundance of fish expected to occur within the project river under un-impaired conditions. The computational framework of TFC models accounts for spatial and temporal variations of the native community and creates a robust, inter-annual representation of the expected native fauna composition at the watershed scale.

The resulting TFC was compared to the existing assemblage of fish species found within the Souhegan River based on fish capture and observation data collected from multiple habitats throughout the river by the Northeast Instream Habitat Program using stream-side electrofishing gear and pre-positioned grids. The status and condition of the Upper and Lower Souhegan River fish communities[1] was evaluated based on this comparison.

We present here two target fish communities, created for the upper and lower portions of the Souhegan River, New Hampshire. The development process is outlined, the resulting communities are presented, and comparisons are made between the TFCs and the existing fish communities to identify deviations from target conditions and evaluate the status of the Souhegan River fish communities.

[1] Despite their unique meanings in community ecology applications, as defined by Fauth et al. (1996), the terms "community" and "assemblage" are used interchangeably in this paper when referring to the fish fauna of the Souhegan River and TFC models.

Methods

Study Area

The study area encompasses the main stem of the 171 square mile Souhegan River watershed from the Massachusetts-New Hampshire border downstream (north-northeast) to its confluence with the Merrimack River in Merrimack, New Hampshire. Based on an initial reconnaissance survey and MesoHABSIM habitat mapping of the river in 2004, the river was divided into eleven representative sites (Figure 1). In the area below site 5, the river exhibits multiple geo-physical differences (e.g. stream order, gradient, dominant substrate type) from the river above that point. At the confluence of Stoney Brook (just above site 5) the stream order of the river changes from third to fourth order, the valley begins to widen, and the gradient of the river becomes less steep. There is also a noticeable change in the dominant substrate type in the river below this point, from large cobble and boulders with bedrock outcrops, to sand and fine gravel. These sudden changes in gradient, stream order, and dominant substrate type coincide with the approximate location of the Milford-Souhegan glacial-drift aquifer, an area of unconsolidated glacial-drift deposits consisting primarily of stratified sand and gravel overlain by more recent alluvium (Harte, 1992). The combined effects of gradient and stream order changes and the sudden change in surficial geology create differences in the available habitat types between the upper and lower portions of the river. Furthermore, the upper portions of the Souhegan River are within Ecoregion 58 **(**Omernik, 1987[2]**)**, the Northeastern Highlands, and the lower portions of the river extend into Ecoregion 59, the Northeastern Coastal Zone (Figure 1). Consequently, differences between the fish communities of the upper and lower Souhegan River were expected to occur. To account for the expected difference in the fish communities associated with these different habitat types, separate TFCs were developed for the upper and lower Souhegan River.

Fish List

A list of species currently or historically found or with the potential to exist within the Souhegan River was compiled using fish distribution references, historical records, and recent collection records (Schmidt, 1986; Scarola, 1987; Hartel et al., 2002; NAI, 2004).

The fish species within the TFC and the Souhegan River existing fish communities were organized into specialized habitat use and pollution tolerance classification guilds based on classifications assigned by Bain (2000) through an extensive literature review (Scott and Crossman, 1973; Pflieger, 1975; Lee et al., 1980; Trautman, 1981; Becker, 1983; Burr and Warren, 1986; Robinson and Buchanon, 1988; Jenkins and Burkhead, 1994, Halliwell et al., 1999). Creek chub, fallfish, longnose dace, longnose sucker, and slimy sculpin were reclassified as fluvial specialists in this study, as in previous target fish community studies within this region, based on their local habitat use patterns (Lang et al., 2001; Kearns et al., 2005). Fish species were also classified based on their thermal requirements, determined from a review of the literature pertinent to the fishes of the northeast region (Scarola, 1987; Halliwell et al., 1999; Langdon, 2001; Hartel et al. 2002; NAI, 2004).

[2] Determination of the zoogeographic similarity of areas is based on an analysis of geology, physiography, vegetation, climate, soils, land use, wildlife and hydrology to identify ecologically similar regions, or Ecoregions

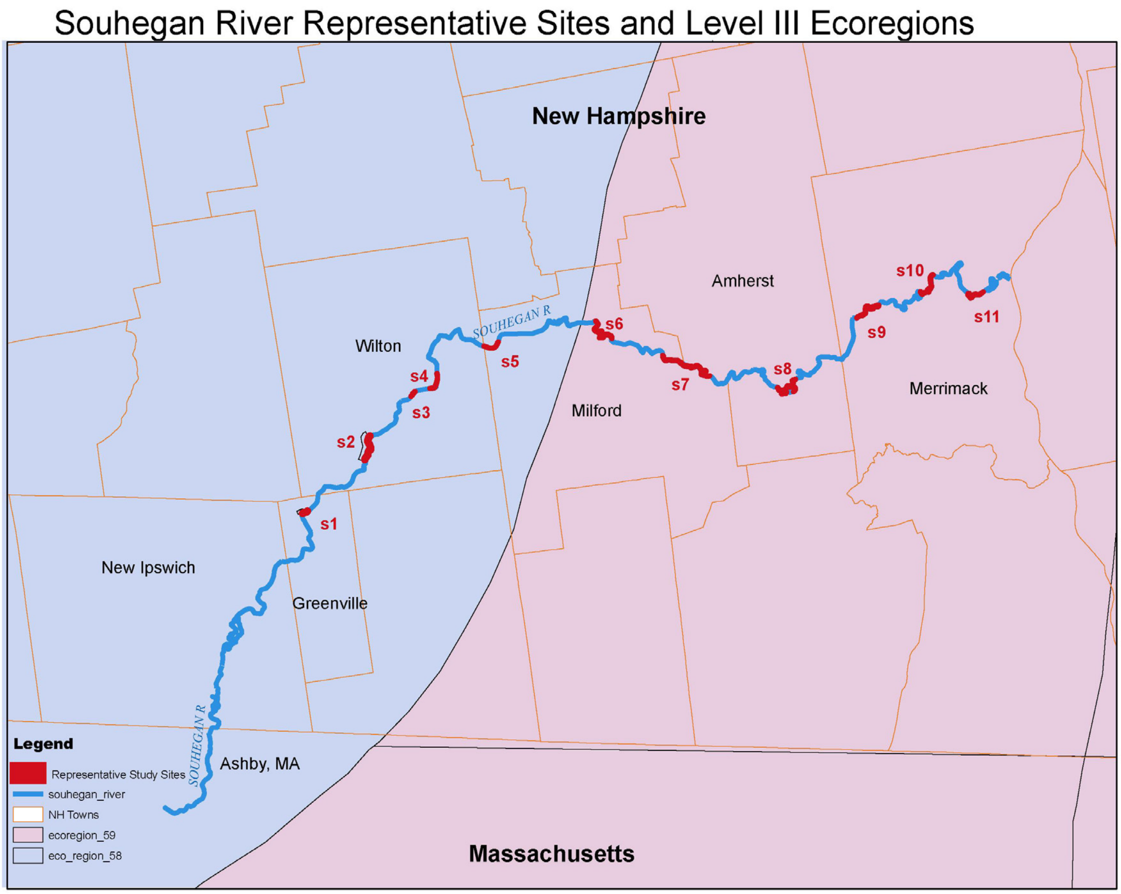

Figure 1. Souhegan River with representative sites and Level III Ecoregions

Reference River Selection

Historical fish collection data from several rivers, similar in geo-physical character and zoogeographic regional location[3] to the Souhegan, and with relatively few ecological disturbances, were used for the calculation of TFCs for the Souhegan River. Initial selection of these rivers was made using ArcMap (ESRI, Inc., 1999-2004) Geographic Information System (GIS) software tools to create a geoprocessing model. Meeting these conditions was dependent upon a river having five geo-physical attributes (square miles of drainage area, stream order, gradient class, elevation class, and percent of calcareous geologic formations) existing in similar magnitude to those of the Souhegan River, and a zoogeographic location within the same Level III Ecoregion (Omernik, 1987). The quantitative parameters of these attributes within the Souhegan River were identified (Table 1) and entered into the geoprocessing model as selection criteria. This model was then applied to a stream

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classification GIS data layer created by The Nature Conservancy (TNC) (TNC, 2003) to select rivers meeting the defined criteria.

Table 1. Parameters of the geo-physical and zoo-geographic attributes of the upper and lower portions of the Souhegan River chosen as criteria for reference river selection.

Lower Souhegan River

Physical Attribute	Selection Parameters
Drainage Area	80-171 sq. miles
Stream Order	4
Gradient Class*	1
Elevation Class**	1
% Calcareous Geology	0
Level III Ecoregion	59

Upper Souhegan River

Physical Attribute	Selection Parameters
Drainage Area	7-80 sq. miles
Stream Order	2-3
Gradient Class	1-2
Elevation Class	1-2
% Calcareous Geology	0
Level III Ecoregion	58

*Gradient Classes: 1 = 0-0.5%, 2 = 0.5-2%, 3 = 2-4%, 4 = 4-10%, 5 = >10%
**Elevation Classes: 1 = 0-800ft., 2 = 800-1700ft., 3 = 1700-2500ft., 4 = 2500ft.+

Using the definition of Kearns et al. (2004)[4], the ecological status of the selected rivers was assessed by judgments of natural resource and fisheries professionals. Rivers that were found to be of poor ecological quality were deemed “impacted” and eliminated from consideration as potential reference rivers. Adequate fish collection data (having more than 10 individuals of the most common species in the sample (Bain & Meixler, 2000) from the remaining quality rivers were gathered and used in the development of both TFCs.

Target Fish Community Development

The fish data used to develop the TFCs were collected by: the New Hampshire Department of Environmental Services (NHDES), the New Hampshire Fish and Game Department (NHFGD), and the Massachusetts Division of Fisheries and Wildlife (MDFW). Geographic coordinates of the fish-data sample sites were superimposed over the selected portions of the reference rivers within Arc GIS. Maps were then generated showing the locations of the sampling sites. Fish data that did not originate from selected suitable portions of the reference rivers were not considered in the formation of the TFC.

Expected proportions of fish species were generated using the method developed by Bain & Meixler (2000). The total number of fish at each site was summed and the totals of each species were divided by this sum, yielding a proportion of the total catch. These species proportions were summed for all sites and the sums of the proportions were then ranked with the species having the greatest sum ranked “1”. All non-native fish species were removed from the data sets prior to calculations of expected proportions. Despite the removal of these species, all of the remaining species maintained the same numerical rank. Next, the reciprocal of each species rank (1/rank) was taken and all of these reciprocals were summed. The

[4] In a similar analysis on the Housatonic River (Kearns et al. 2004), quality rivers were defined as being “relatively unimpaired, undammed, and undeveloped with few water withdrawals, good water quality, and a similar temperature regime.”

reciprocal rank of each individual species was then divided by the total sum of all reciprocal ranks to determine the expected proportion of each individual species.

Souhegan River Fish Sampling

A survey of the Upper Souhegan River fish community was conducted in July and August of 2005. Surveys were conducted using 6 m^2, pre-positioned electrofishing grids. This method had been proven by Bain (1985) as an effective method of sampling fish for habitat related studies, and has been successfully applied by NEIHP to investigate fish community and habitat relationships on the Quinebaug, Pomperaug, and Eightmile Rivers in Connecticut.

A survey of the Lower Souhegan River fish community was conducted in August of 2005. Because of the consistently deep water found throughout the lower Souhegan, grid elecrofishing was not possible. The Lower Souhegan was, as a result, surveyed using snorkeling equipment to make underwater observations of fish within previously selected HMU located throughout six representative sites of the lower river in a method similar to the one used by Bult et al. (1998).

Existing Fish Community Evaluation

Evaluation of the status of the fish fauna in the Souhegan River was accomplished using Novak and Bode's (1992) percent model affinity procedure. This procedure yields values from 0 to 100 to describe the extent to which the Souhegan River fish community is similar to the TFC. Higher percent model affinity values indicate higher degrees of similarity between the communities. These values are calculated as:

$$\text{Percent similarity} = 100 - 0.5\,(\text{Sum}\,|\text{target P} - \text{observed P}|)$$

where: P = proportions of each species in the community or collection

The TFC and the existing fish communities were then compared again based on the proportions of habitat use, pollution tolerance, and thermal regime classification guilds within the communities. Differences between proportions of individual species in the TFCs and the existing fish communities of the Souhegan River were also analyzed to evaluate the status of individual fish species within the river. An analysis of the percentage differences between target proportions (TFC) and existing proportions of fish species was used to determine which were under- represented, existing in expected proportions, or overly abundant within the upper and lower portions of the Souhegan River. Calculated as:

$$\text{Percentage difference} = |\text{target P} - \text{observed P}| \,/\, \text{target P}$$

Species existing in proportions more than 50% lower than expected were considered underrepresented and species existing in proportions more than 50% higher than expected were considered overly abundant. Missing native species and the presence of non-native or introduced fish species and their proportion of the existing community were identified.

Results

Fish List

Based on our review of fish distribution references, historical records, and recent collection records, thirty-five species, from eleven different families, were found to occur historically or currently, or were considered to have the potential to occur within the Souhegan River (Table 2). The list contains a variety of species, both native and introduced, with known and potential occurrences and a full range of habitat use, pollution tolerance, and thermal regime classifications.

Quality Reference Rivers

Table 3 lists all potential reference rivers found to be geo-physically and zoo-geographically similar to the upper Souhegan River and lower Souhegan River and gives reasons for those that were rejected. Those that were not rejected make up the quality reference rivers from which fish data were used to develop the Upper and Lower Souhegan River TFCs.

Table 2. Species expected or with potential to occur in the Souhegan River. Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderate/intermediate (M), or tolerant (T) pollution tolerances, and Cold, Cool*, or Warm water thermal regimes are given for each species.

Family Common name	Genus	Species	Native or Introduced	Habitat use classification	Pollution tolerance	Thermal regime
Petromyzontidae						
Sea lamprey	*Petromyzon*	*marinus*	N	FD		
Anguillidae						
American eel	*Anguilla*	*rostrata*	N	FD	T	Cool
Clupeidae						
Alewife	*Alosa*	*pseudoherangus*	N	FD		
American shad	*Alosa*	*sapidissima*	N	FD		
Salmonidae						
Rainbow trout	*Oncorhynchus*	*mykiss*	I	FD	I	Cold
Atlantic salmon	*Salmo*	*salar*	N	FS	I	Cold
Brown trout	*Salmo*	*trutta*	I	FD	I	Cool
Brook trout (char)	*Salvelinus*	*fontinalis*	N	FS	I	Cold
Escocidae						
Redfin pickerel	*Esox*	*americanus*	N	MG	M	Warm
Chain pickerel	*Esox*	*niger*	N	MG	M	Warm
Cyprinidae						
Common carp	*Cyprinus*	*carpio*	I	MG	T	Warm
Common shiner	*Luxilus*	*cornatus*	N	FD	M	Cool
Golden shiner	*Notemigonus*	*crysoleucas*	N	MG	T	Cool
Spottail shiner	*Notropis*	*hudsonius*	N	MG	M	Cool
Blacknose dace	*Rhinichthys*	*atratulus*	N	FS	T	Cool
Longnose dace	*Rhinichthys*	*cataractae*	N	FS	M	Cool
Creek chub	*Semotilus*	*atromaculatus*	N	FS	T	Cool
Fallfish	*Semotilus*	*corporalis*	N	FS	M	Cool
Catostomidae						
White sucker	*Catostomus*	*commersoni*	N	FD	T	Cool
Longnose sucker	*Catostomus*	*catostomus*	N	FS	M	Cold
Creek chubsucker	*Erimyzon*	*oblongus*	N	FS	I	Cool
Ictaluridae						
Yellow bullhead	*Ameiurus*	*natalis*	I	MG	T	Warm
Brown bullhead	*Ameiurus*	*nebulosus*	N	MG	T	Warm
Margined madtom	*Noturus*	*insignis*	I	MG	T	Warm
Centrarchidae						
Banded sunfish	*Enneacanthus*	*obesus*	N	MG	M	Warm
Redbreast sunfish	*Lepomis*	*auritus*	N	MG	M	Warm
Pumpkinseed	*Lepomis*	*gibbosus*	N	MG	M	Warm
Bluegill	*Lepomis*	*macrochirus*	I	MG	T	Warm
Smallmouth bass	*Micropterus*	*dolomieu*	I	MG	M	Warm
Largemouth bass	*Micropterus*	*salmoides*	I	MG	M	Warm
Black crappie	*Pomoxis*	*nigromaculatus*	I	MG	M	Warm
Percidae						
Swamp darter	*Etheostoma*	*fusiforme*	N	MG	M	Warm
Tesselated darter	*Etheostoma*	*olmstedi*	N	FS	M	Cool
Yellow perch	*Perca*	*flavescens*	N	MG	M	Cool
Cottidae						
Slimy sculpin	*Cottus*	*cognatus*	N	FS	I	Cold

*** Species tolerating a wide range of water temperatures from cold to warm.**

Table 3. The list of rivers identified as physically and zoo-geographically similar to the Souhegan River (potential reference rivers) and reasons for elimination of those not selected as quality reference rivers.

Upper Souhegan Reference rivers	Selected as Reference river	Reason for rejection
Ashuelot River, SB	No	Impacted
Blackwater River, NH	No	Lack of fish data
Burnshirt River, MA	Yes	--
Chickley River, MA	Yes	--
Cold River, MA	Yes	--
Contoocook River, North Branch, NH	No	Impacted
Cocheco River, NH	No	Impacted
Indian River, NH	No	Lack of fish data
Mascoma River, NH	Yes	--
Piscataquog River, Middle Branch, NH	Yes	--
Piscataquog River, South Branch, NH	Yes	--
Soucook River, NH	No	Insufficient fish data
Sugar River, North Branch, NH	No	Lack of fish data
Suncook River, NH	Yes	--
Swift River, East Branch, MA	Yes	--
Westfield River, East Branch, MA	Yes	--
Westfield River, Middle Branch, MA	Yes	--
Westfield River, West Branch, MA	Yes	--

Lower Souhegan Reference rivers	Selected as Reference river	Reason for rejection
Assebet River, MA	No	Impacted
Burnshirt River, MA	No	Insufficient fish data
Charles River, MA	No	Impacted
Neponset River, MA	No	Impacted
Quaboag River, MA	Yes	--
Quinnebaug, River, MA & CT	No	Impacted
Quinnipiac River, CT	Yes	--
Soucook River, NH	Yes	--
Suncook River, NH	No	Insufficient fish data
Taunton River, MA	No	Impacted
Ware River, MA	Yes	--
Willimantic River, CT	Yes	--

Upper Souhegan River Target Fish Community

The Upper Souhegan River TFC (U-TFC) was created using fish collection data from the eleven quality upper reference rivers identified in Table 3. The resulting community was a diverse one dominated by fluvial species. The ten most abundant species in the U-TFC were blacknose dace (29%), longnose dace (15%), common shiner (10%), common white sucker (7%), fallfish (6%), slimy sculpin (5%), Eastern brook trout (4%), longnose sucker (4%), redbreast sunfish (3%), and Atlantic salmon (3%). The remaining species consisted of brown bullhead, creek chub, yellow perch, pumpkinseed sunfish, golden shiner, Eastern chain pickerel, spottail shiner, and American eel, and accounted for a combined total of 14% of the expected community. A chart representing the U-TFC is shown in Figure 2. The community is comprised of fluvial specialist (67%), fluvial dependent (18%), and macrohabitat generalist (15%) species (Figure 3). The final species list, mean ranks, and expected proportions of the U-TFC are presented in Table 4.

Lower Souhegan River Target Fish Community

The Lower Souhegan River TFC (L-TFC) was created using fish collection data from the five quality lower reference rivers also identified in Table 3. The L-TFC is as equally diverse as the U-TFC and is also dominated by fluvial species. The ten most abundant species in the L-TFC were common white sucker (32%), fallfish (15%), common shiner (10%), blacknose dace (8%), longnose dace (6%), yellow perch (5%), pumpkinseed sunfish (4%), brown bullhead (3%), tessellated darter (3%), and Eastern chain pickerel (3%). The remaining species, redbreast sunfish, golden shiner, creek chubsucker, American eel, spottail shiner, and Eastern brook trout account for a combined total of 11% of the expected community (Figure 4). The community is comprised of fluvial specialist (35%), fluvial dependent (42%), and macrohabitat generalist (23%) species (Figure 5). The data used to generate the L-TFC, calculated mean ranks, and expected proportions are displayed as Table 5.

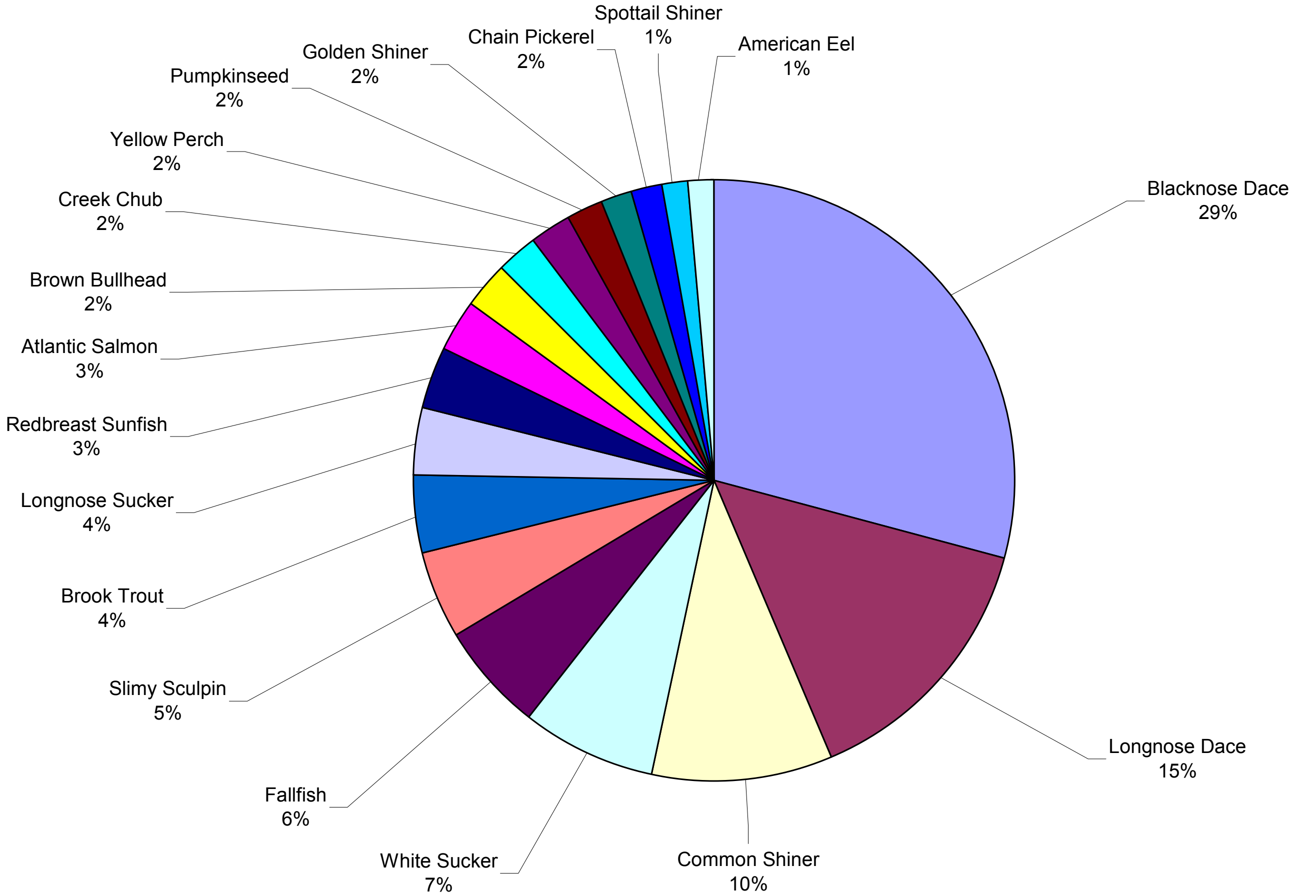

Figure 2. Upper Souhegan River Target Fish Community (U-TFC).

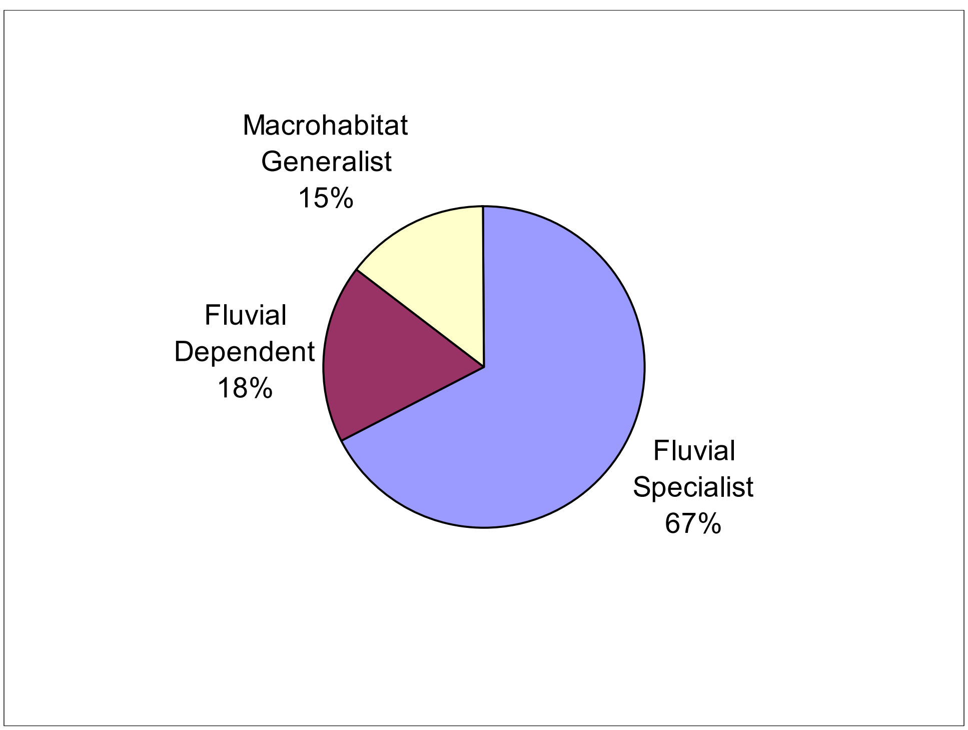

Figure 3. U-TFC based on habitat use classification guilds.

Table 4. Fish captures in reference rivers used for development of Target Fish Community for Upper Souhegan River with calculated mean ranks and expected proportions.

Common Name	Scientific Name	Burnshirt River	Chickley River	Cold River	Mascoma River	Piscataquog River, M.B.	Piscataquog River, S.B.	Suncook River	Swift River, E.B.	Westfield River, E.B.	Westfield River, M.B.	Westfield River, W.B.	Mean Rank	Expected Proportion (*f*)
Blacknose Dace	*Rhinichthys atratulus*	4	54	159	24	89	138	4	85	111	105	95	1	29%
Longnose Dace	*Rhinichthys cataractae*	2	17	17	18	50	102	1	94	31	24	58	2	15%
Common Shiner	*Luxilus cornutus*	6		41	2	71	109	31		9	3	6	3	10%
White Sucker	*Catostomus commersoni*	39	4	15	18	7		3	70	22	30	27	4	7%
Fallfish	*Semotilus corporalis*	114			3	35	14	5	44			22	5	6%
Slimy Sculpin	*Cottus cognatus*		35	27						9	17	12	6	5%
Brook Trout	*Salvelinus fontinalis*		19	7					18	5	11	10	7	4%
Longnose Sucker	*Catostomus catostomus*		11	26		11	38						8	4%
Redbreast Sunfish	*Lepomis auritus*				2			10					9	3%
Atlantic Salmon	*Salmo salar*					23	42						10	3%
Brown Bullhead	*Ameiurus nobulosus*	19		2		1			13			1	12	2%
Creek Chub	*Semotilus atromaculatus*			9	1			2			4		13	2%
Yellow Perch	*Perca flavescens*								33				14	2%
Pumpkinseed	*Lepomis gibbosus*					2	2		13	1		5	15	2%
Golden Shiner	*Notemigonus crysoleucas*			6		9	9						16	2%
Chain Pickerel	*Esox niger*	10					1		3				17	2%
Spottail Shiner	*Notropis hudsonius*					2	3						21	1%
American Eel	*Anguilla rostrata*		1										22	1%
Totals:		194	141	309	68	300	458	56	373	188	194	236		100%

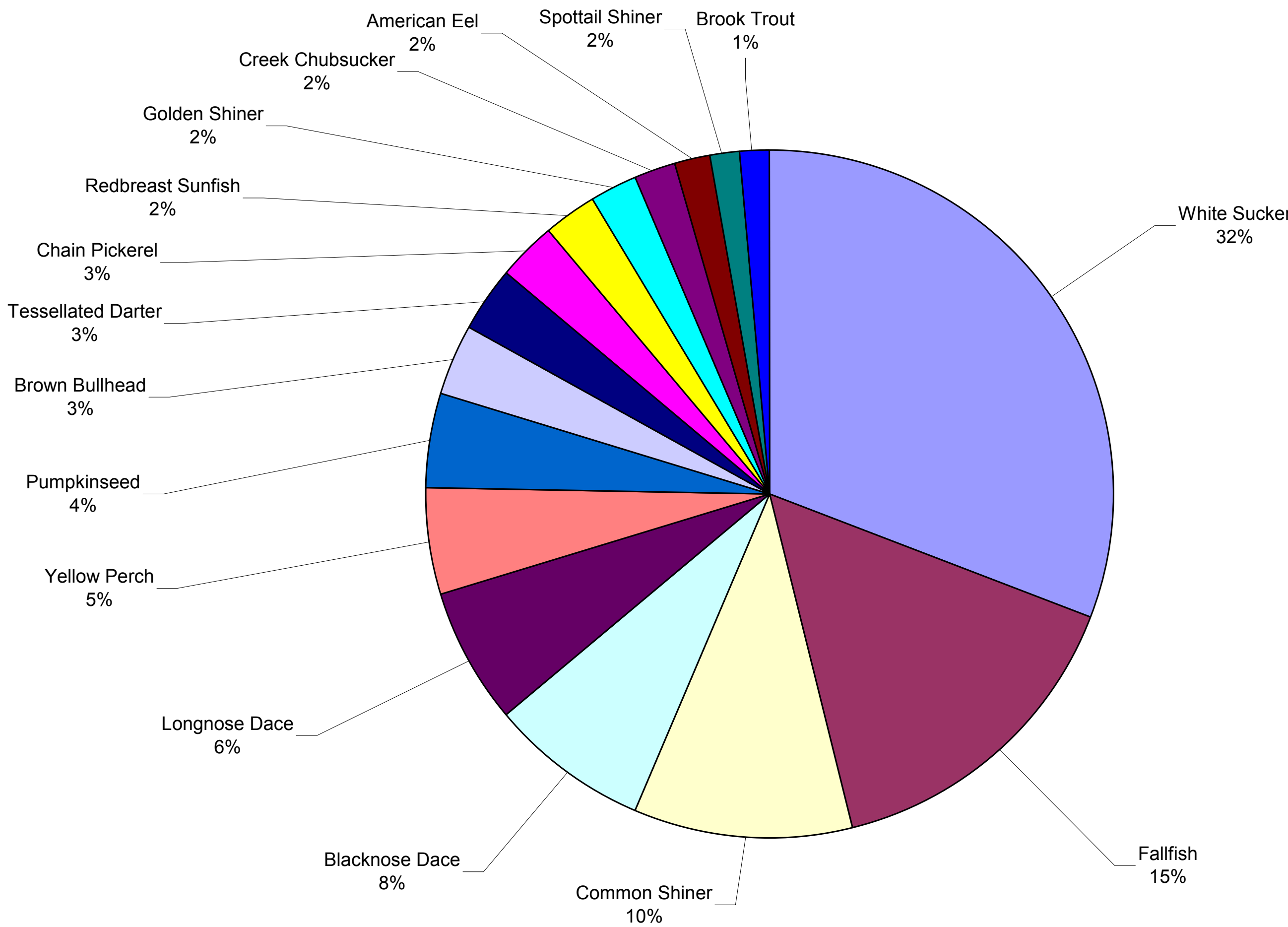

Figure 4. Lower Souhegan River Target Fish Community (L-TFC).

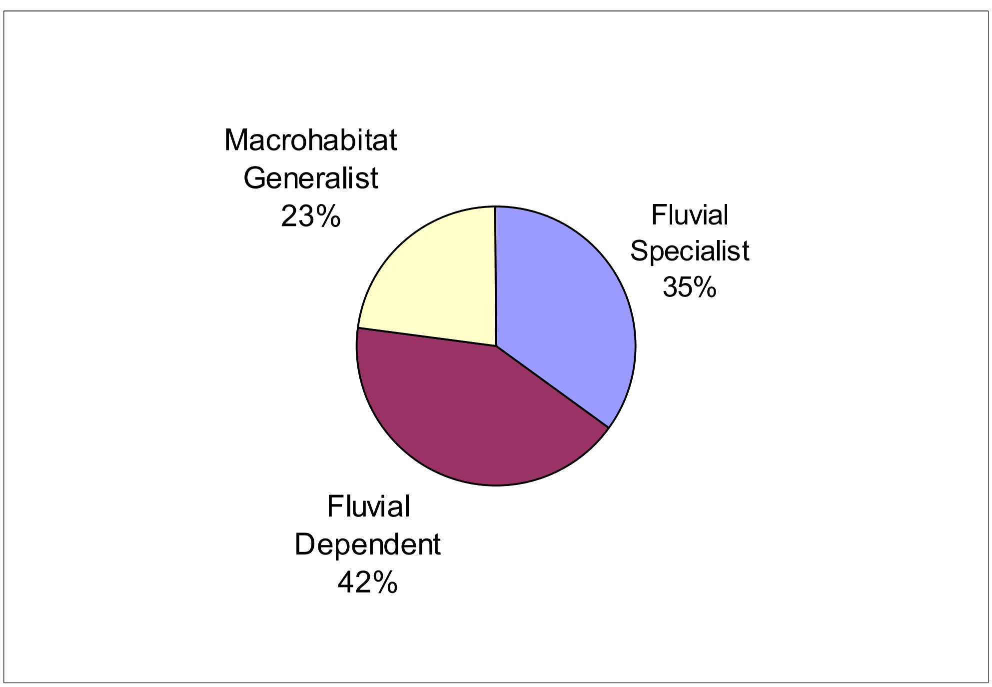

Figure 5. L-TFC based on habitat use classification guilds.

Table 5. Lower Souhegan River Target Fish Community species list with mean ranks and expected proportions of species.

Common Name	Scientific Name	Quaboag River	Quinnipiac River	Soucook River	Ware River	Willimantic River	Mean Ranks	Expected Proportion (*f*)
White Sucker	*Catostomus commersoni*	69	625	2	283	1092	1	31%
Fallfish	*Semotilus corporalis*	14	95	1	227	3194	2	15%
Common Shiner	*Luxilus cornutus*			100	32	1440	3	10%
Blacknose Dace	*Rhinichthys atratulus*	14		117	5	557	4	8%
Longnose Dace	*Rhinichthys cataractae*	69	225	53	70		5	6%
Yellow Perch	*Perca flavescens*	193	30		203	193	6	5%
Pumpkinseed	*Lepomis gibbosus*	208	10		96	50	7	4%
Brown Bullhead	*Ameiurus nobulosus*	138		2	14	2	9	3%
Tessellated Darter	*Etheostoma olmstedi*		135	2		104	10	3%
Chain Pickerel	*Esox niger*	128			9	7	11	3%
Redbreast Sunfish	*Lepomis auritus*	82				150	13	2%
Golden Shiner	*Notemigonus crysoleucas*	104			1	22	14	2%
Creek Chubsucker	*Erimyzon oblongus*	91			9		16	2%
American Eel	*Anguilla rostrata*		75	2		21	18	2%
Spottail Shiner	*Notropis hudsonius*			6		16	20	2%
Brook Trout	*Salvelinus fontinalis*		5	1			24	1%
Totals:		1110	1200	286	949	6848		100%

Upper Souhegan River Existing Fish Community

The existing fish community of the upper segment of the Souhegan River, as sampled in the summer of 2005, was dominated by native fluvial species (87% fluvial specialist and 8% fluvial dependent), with a small proportion of macrohabitat generalists (5%). The community consisted of blacknose dace (55%), longnose dace (25%), fallfish (6%), common shiner (5%), white sucker (3%), yellow perch (2%), largemouth bass (2%), and Atlantic salmon (1%). Pumpkinseed, golden shiner, and brown trout, combined, made up the remaining 1% of the community. A total of 11 different fish species were sampled in the upper segment of the Souhegan River, 9 of which were native. The only two non-native fish species sampled in the upper Souhegan, largemouth bass and brown trout, accounted for less than 3% of the community (Figure 6).

Lower Souhegan River Existing Fish Community

The existing fish community of the lower segment of the Souhegan River, also surveyed in the summer of 2005, was dominated by common shiner (30%), fallfish (20%), blacknose dace (16%), white sucker (13%), redbreast sunfish (13%), longnose dace (4%), largemouth bass (2%) and golden shiner (1%). The lower Souhegan fish community consisted of primarily native fluvial species (41% fluvial specialist and % fluvial dependent), with a considerably lesser proportion of macrohabitat generalists (16%). The remaining species, yellow bullhead, brown trout, creek chubsucker, chain pickerel, yellow perch, bluegill, rainbow trout, and pumpkinseed accounted for a combined total of less than 2% of the community. A total of 16 different fish species were sampled in the lower segment of the Souhegan River, 11 of which were native. The five non-native species sampled in the lower Souhegan, largemouth bass, yellow bullhead, brown trout, bluegill, and rainbow trout accounted for a combined total of less than 3% of the community (Figure 7).

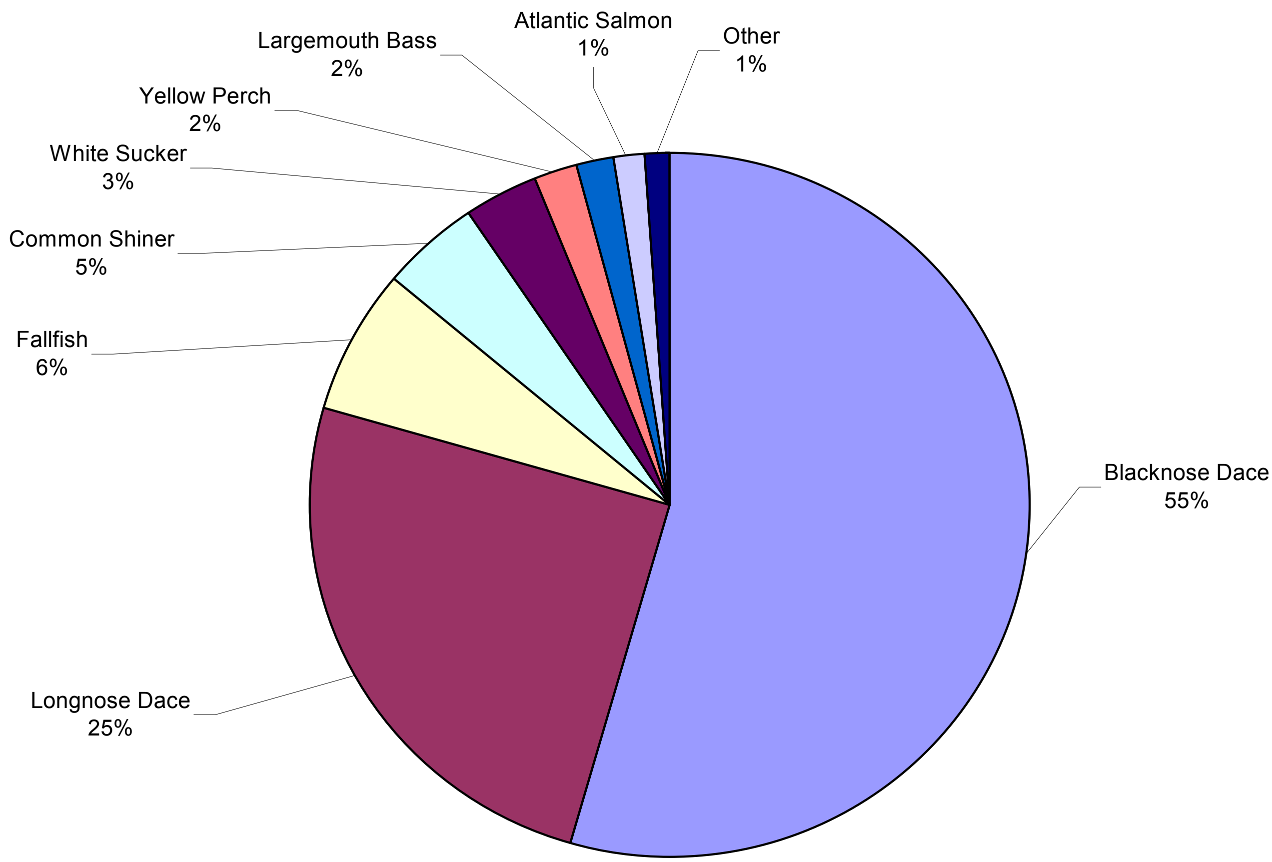

Figure 6. Upper Souhegan River existing fish community.

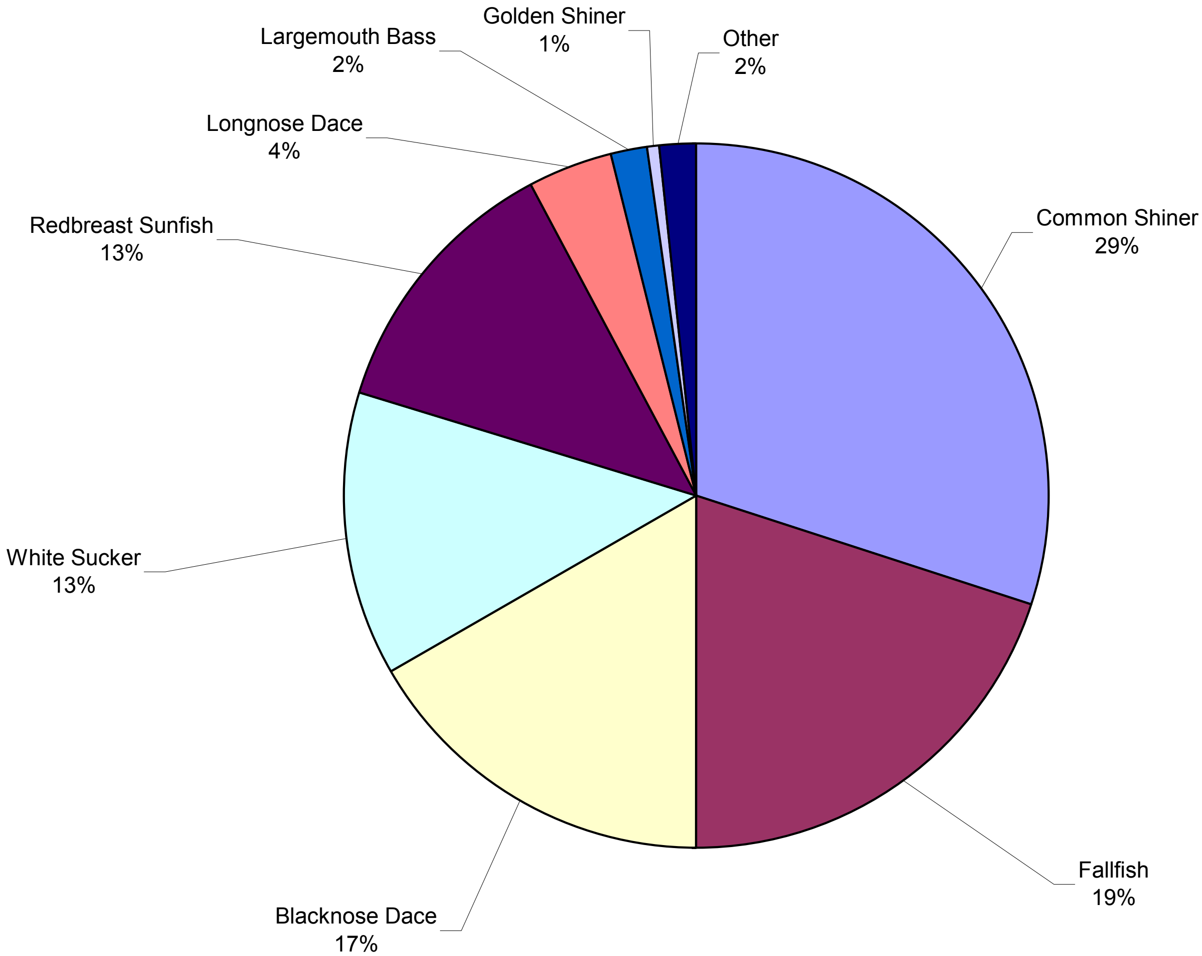

Figure 7. Lower Souhegan River existing fish community

Existing Fish Community Evaluations

A comparison of the similarity between the upper Souhegan River fish community and the U-TFC was made using the percent model affinity procedure. The upper Souhegan River fish community scored an affinity value of 61% similarity to the U-TFC. The lower Souhegan River fish community scored an affinity index value of 54% similarity to the L-TFC. These affinity value indexes allow us to evaluate the fauna of the Souhegan River on a community scale. Community scale analyses were also conducted on proportions of species within the TFC and existing fish communities based on habitat use, pollution tolerance, and thermal regime classification guilds to further evaluate the status of the Souhegan River fish communities.

Comparison of the Upper Souhegan River existing fish community proportions to the U-TFC proportions based on habitat use guilds (Figure 8) revealed an under-representation of fluvial dependent and macrohabitat generalist species, and a slight overabundance of fluvial specialist species in the existing fish community. The most significant of these deviations is the 69% difference between expected and existing proportions of macrohabitat generalist species. The differences between expected and existing proportions of fluvial specialist and fluvial dependent species are 30% and 55%, respectively.

The U-TFC consisted of 12% pollution intolerant species, 44% moderately tolerant species, and 44% tolerant species. The Upper Souhegan existing fish community was comprised of 1% pollution intolerant species, 40% moderately tolerant species, and 59% tolerant species (Figure 9). A comparison between the two communities illustrated a highly significant under-representation of pollution intolerant species in the existing fish community of the Upper Souhegan with proportions differing by 88%. Moderately tolerant species were considerably similar (8%), while pollution tolerant species were slightly overabundant in the existing community with a difference of 32% between the two communities.

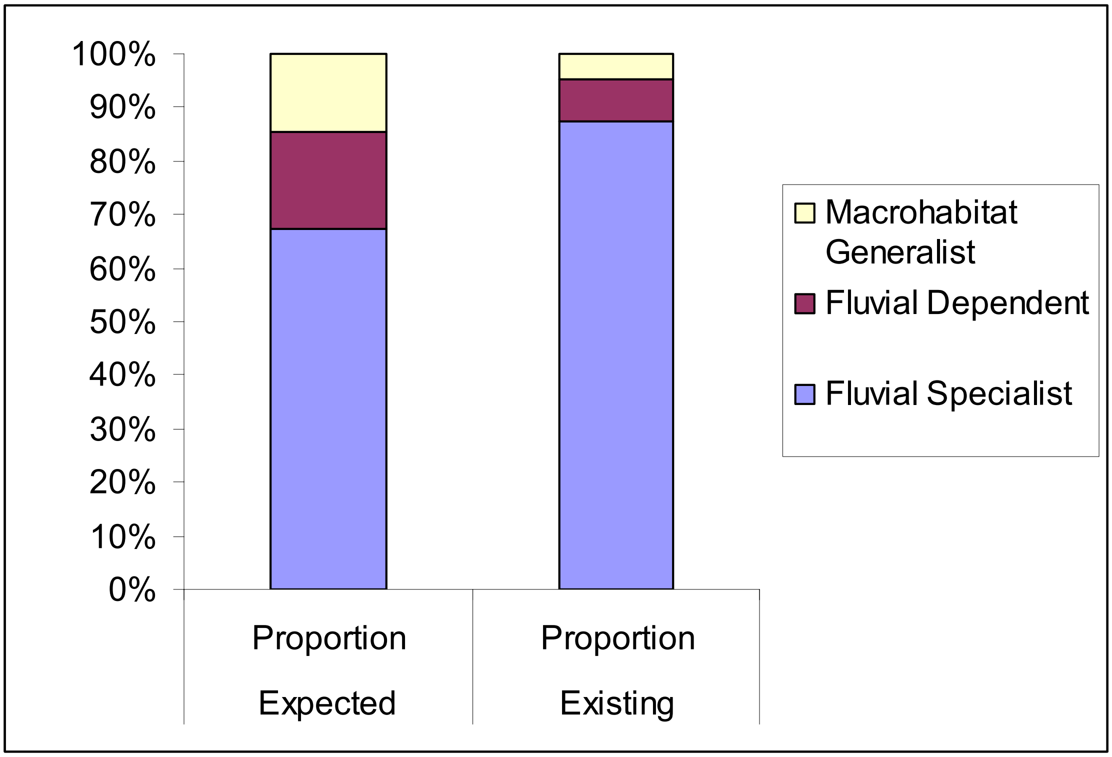

Figure 8. Comparison of the proportions of habitat use classification guilds between the U-TFC and Upper Souhegan River existing fish community.

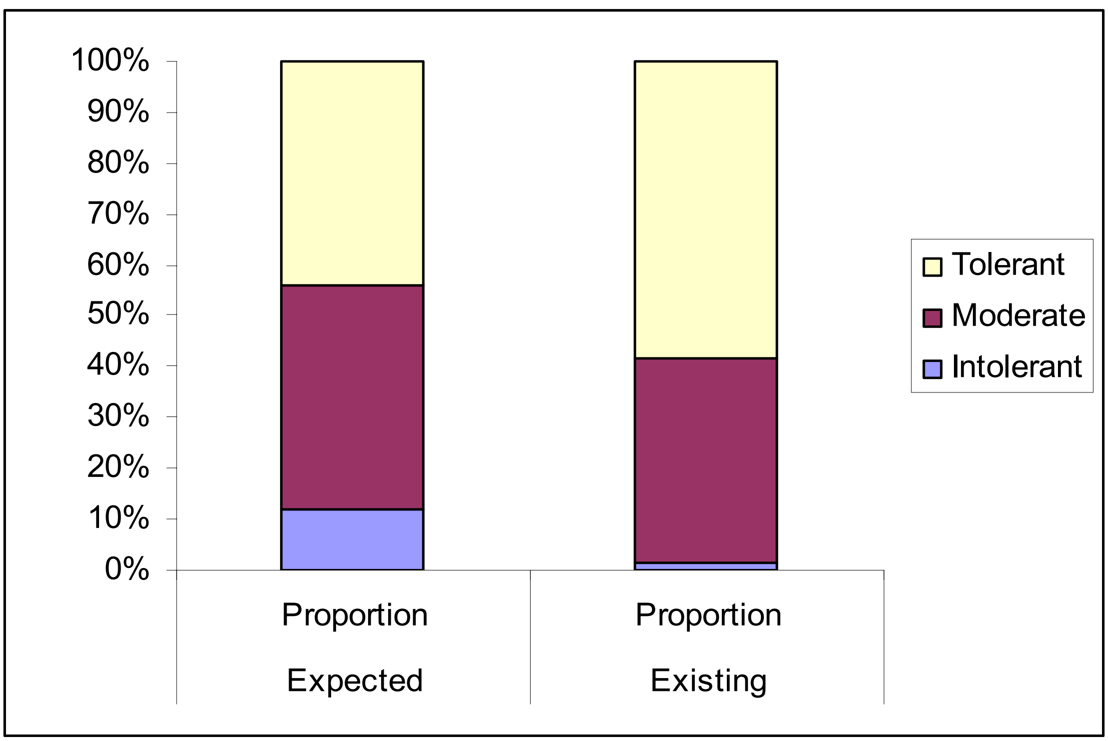

Figure 9. Comparison of the proportions of pollution tolerance classification guilds between the U-TFC and Upper Souhegan River existing fish community.

The U-TFC consisted of 16% cold water species, 75% cool water species, and 9% warm water species. The Upper Souhegan existing fish community was comprised of 1% cold water species, 97% cool water species, and 2% warm water species (Figure 10). Cool water species, or species tolerating a wide range of water temperatures from warm to cold, accounted for a major portion of both communities yet were slightly overabundant in the existing community. Conversely, cold water and warm water species accounted for considerably lesser portions of both communities and were both significantly under-represented in the existing community. The most significant difference (92%) was between cold water species, followed by warm water (77%), and then cool water species (29%).

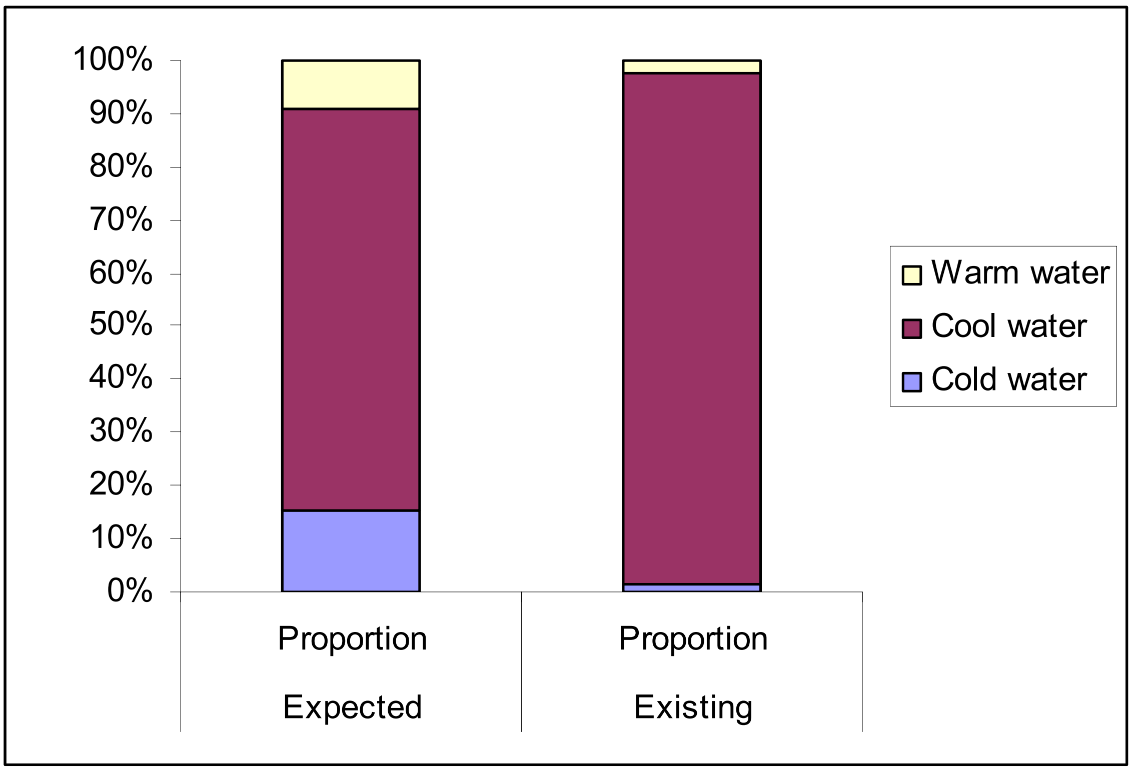

Figure 10. Comparison of the proportions of thermal regime classification guilds between the U-TFC and Upper Souhegan River existing fish community.

Comparison of the Lower Souhegan existing fish community to the L-TFC based on habitat use guilds (Figure 11) revealed a close similarity between the two communities. The most significant difference (35%) was between the proportions of macrohabitat generalist species, which are slightly underrepresented in the existing community. Proportions of fluvial specialists were only slightly different (16%), while there was almost no difference between proportions of fluvial dependent species (4%).

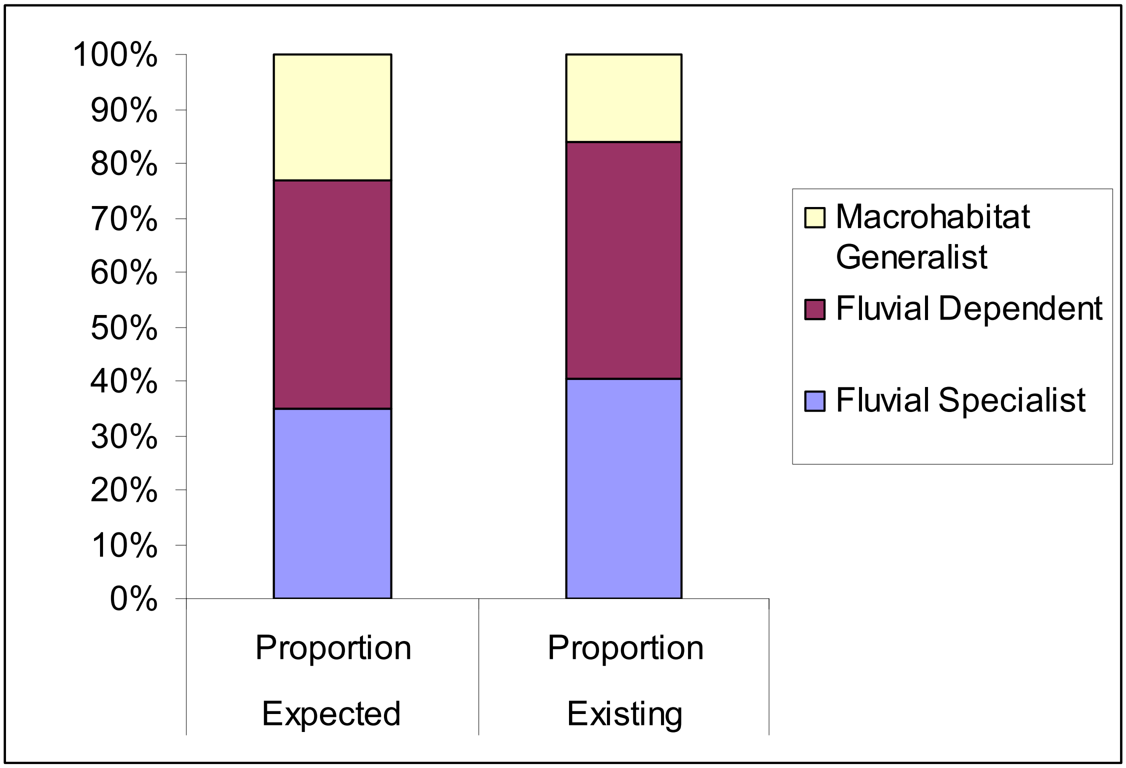

Figure 11. Comparison of the proportions of habitat use classification guilds between the L-TFC and Lower Souhegan River existing fish community.

The L-TFC consisted of 3% pollution intolerant species, 51% moderately tolerant species, and 46% tolerant species. The Lower Souhegan existing fish community was comprised of 1% pollution intolerant species, 68% moderately tolerant species, and 31% tolerant species (Figure 12). When the two communities were compared based on these pollution tolerance guilds, a significant difference (79%) was found between the existing and target proportions of pollution intolerant species. Considerable differences were also noticed between the expected and existing proportions of moderately tolerant (34%) and tolerant species (33%). Existing proportions of moderately tolerant species were only slightly higher than expected whereas; proportions of tolerant species were slightly lower. Existing proportions of intolerant species, however where significantly lower than expected.

The L-TFC consisted of 1% cold water species, 86% cool water species, and 13% warm water species. The Lower Souhegan existing fish community was comprised of 0% cold water species, 85% cool water species, and 15% warm water species (Figure13). A comparison between the two communities illustrated a significant under-representation of cold water species in the existing fish community of the Lower Souhegan with proportions differing by 89%. The proportions of cool water species were almost identical, while proportions of warm water species only slightly different (15%).

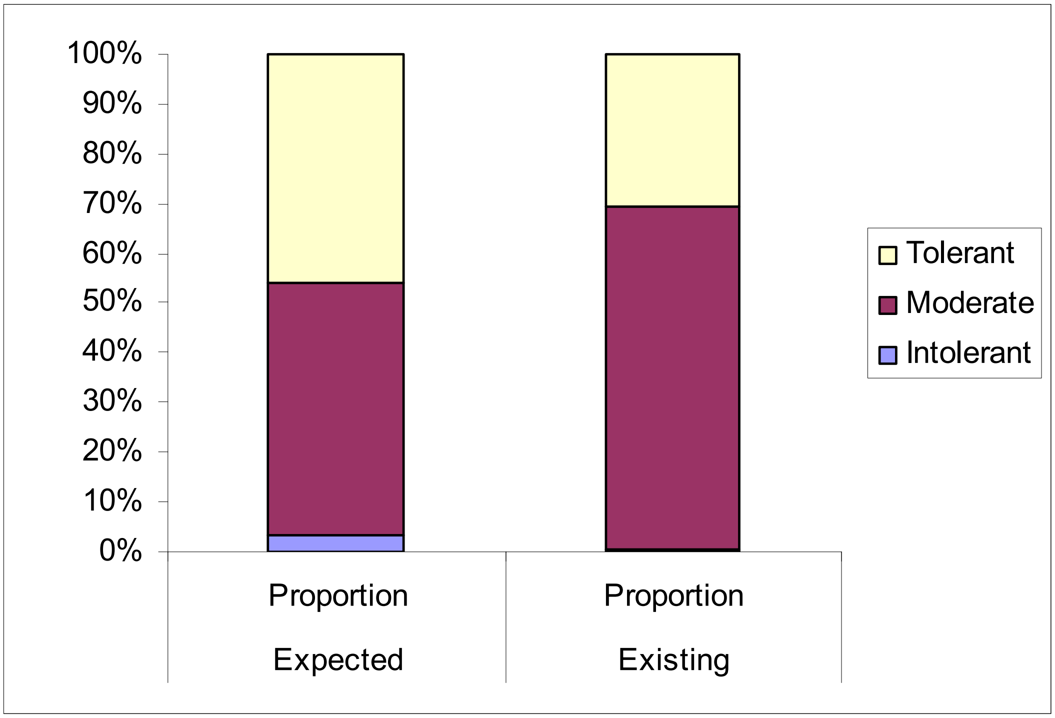

Figure 12. Comparison of the proportions of pollution tolerance classification guilds between the L-TFC and Lower Souhegan River existing fish community.

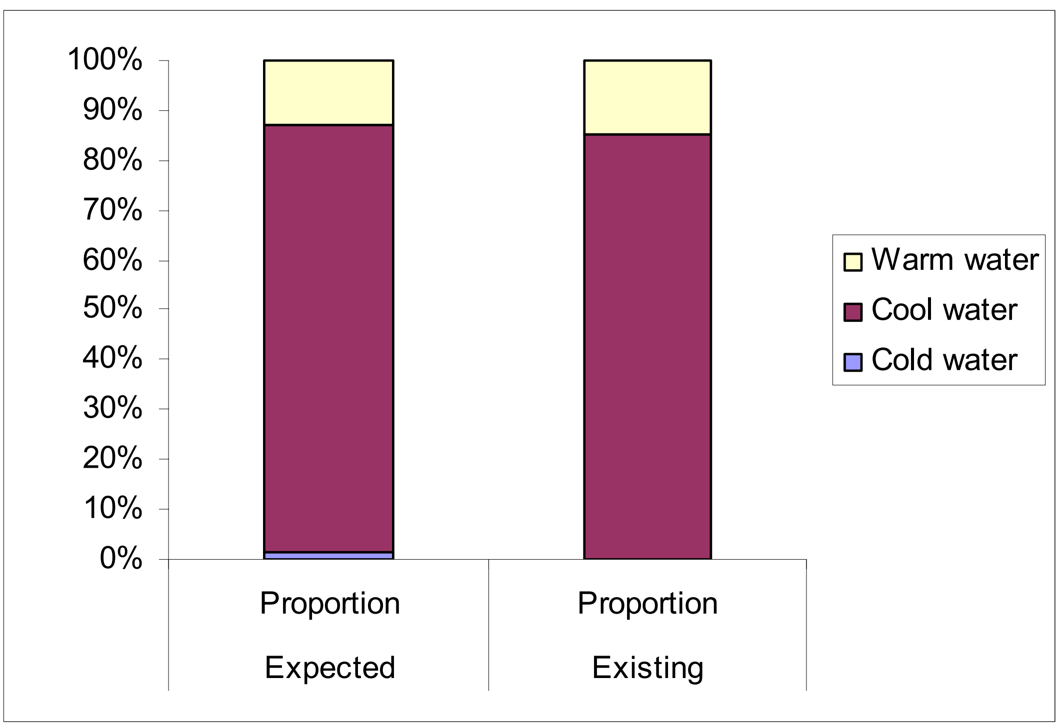

Figure 13. Comparison of the proportions of thermal regime classification guilds between the L-TFC and Lower Souhegan River existing fish community.

Differences between proportions of individual species in the TFC and the existing fish communities of the Souhegan River were analyzed using the calculated percentage differences between the expected (TFC) and existing proportions to evaluate the status of individual fish species within the river.

Within the Upper Souhegan River existing fish community, Atlantic salmon, common shiner, golden shiner, pumkinseed and white sucker were determined to be under-represented in the Upper Souhegan River existing fish community, while blacknose dace and longnose dace were found in greater abundances than predicted target community proportions. Brown trout and largemouth bass represented the only two non-native or introduced species in the Upper Souhegan fish community. (Table 6).

In the Lower Souhegan River existing fish community chain pickerel, creek chub sucker, pumpkinseed, yellow perch and white sucker were found to be under-represented, while blacknose dace, common shiner and redbreast sunfish were considered to be over-represented. Introduced species existing in the Lower Souhegan River were bluegill, brown trout, largemouth bass, rainbow trout, and yellow bullhead. (Table 7).

Table 6. Comparison of proportions of fish species between the U-TFC[5] and Upper Souhegan River existing fish community identifying under-represented, existing as expected, overly abundant, missing, and introduced species in the upper Souhegan River. Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderate (M), or tolerant (T) pollution tolerances, and Cold, Cool, or Cold water thermal regimes are given for each species.

Species	Proportion of Target Fish Community	Proportion of Existing Fish Community	Native or Introduced	Habitat use Classification	Pollution Tolerance	Thermal Regime
Underrepresented native target fish species						
Atlantic salmon	3%	1%	N	FS	I	Cold
Common shiner	10%	5%	N	FD	M	Cool
Golden shiner	2%	<1%	N	MG	T	Cool
Pumpkinseed	2%	<1%	N	MG	M	Warm
White sucker	7%	3%	N	FD	T	Cool
Target fish species recorded as expected						
Fallfish	6%	6%	N	FS	M	Cool
Yellow perch	2%	2%	N	MG	M	Cool
Overly abundant native target fish species						
Blacknose dace	29%	55%	N	FS	T	Cool
Longnose dace	15%	25%	N	FS	M	Cool
Missing native target fish species						
American eel	1%	0%	N	FD	T	Cool
Brown bullhead	2%	0%	N	MG	T	Warm
Chain pickerel	2%	0%	N	MG	M	Warm
Creek chub	2%	0%	N	FS	T	Cool
Eastern brook trout	4%	0%	N	FS	I	Cold
Longnose sucker	4%	0%	N	FS	M	Cold
Redbreast sunfish	3%	0%	N	MG	M	Warm
Slimy sculpin	5%	0%	N	FS	I	Cold
Spottail shiner	1%	0%	N	MG	M	Cool
Introduced species present in the existing fish community						
Brown trout	0%	<1%	I	FD	I	Cool
Largemouth bass	0%	2%	I	MG	M	Warm

[5] Proportions of American eel and Atlantic salmon may be under-represented in the TFC due to the regional decline and extirpation, respectively, of these diadromous species resulting from migratory barriers created by the construction of dams in the lower portions of New England watersheds.

Table 7. Comparison of proportions of fish species between the L-TFC and Lower Souhegan River existing fish community identifying under-represented, existing as expected, overly abundant, missing, and introduced species in the upper Souhegan River. Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderate (M), or tolerant (T) pollution tolerances, and Cold, Cool, or Cold water thermal regimes are given for each species.

Species	Proportion of Target Fish Community	Proportion of Existing Fish Community	Native or Introduced	Habitat use Classification	Pollution Tolerance	Thermal Regime
Underrepresented native target fish species						
Chain pickerel	3%	<1%	N	MG	M	Warm
Creek chubsucker	2%	<1%	N	FS	I	Cool
Pumpkinseed	4%	<1%	N	MG	M	Warm
Yellow perch	5%	<1%	N	MG	M	Cool
White sucker	31%	13%	N	FD	T	Cool
Target fish species recorded as expected						
Fallfish	15%	20%	N	FS	M	Cool
Golden shiner	2%	1%	N	MG	T	Cool
Longnose dace	6%	4%	N	FS	M	Cool
Overly abundant native target fish species						
Blacknose dace	8%	17%	N	FS	T	Cool
Common shiner	10%	30%	N	FD	M	Cool
Redbreast sunfish	2%	13%	N	MG	M	Warm
Missing native target fish species						
American eel	2%	0%	N	FD	T	Cool
Brown bullhead	3%	0%	N	MG	T	Warm
Eastern brook trout	1%	0%	N	FS	I	Cold
Spottail shiner	2%	0%	N	MG	M	Cool
Tessellated darter	3%	0%	N	FS	M	Cool
Introduced species present in the existing fish community						
Bluegill	NA	<1%	I	MG	T	Warm
Brown trout	NA	<1%	I	FD	I	Cool
Largemouth bass	NA	2%	I	MG	M	Warm
Rainbow trout	NA	<1%	I	FD	I	Cold
Yellow bullhead	NA	<1%	I	MG	T	Warm

Discussion

The Target Fish Communities developed for the Souhegan River provide a method for evaluating the existing fish communities of the upper and lower portions of the river. They are similar to previous target fish communities developed for other rivers within the region (Bain and Meixler, 2000; Kearns et al. 2004; Meixler, 2005) in their composition of fluvial and macrohabitat generalist species, are feasible, attainable, and instrumental to the evaluation of the status of flow dependent fish species within the Souhegan River.

Development of a list of species known to occur or with the potential to occur, within the Souhegan, was accomplished based on a review of recent and historical fish collection records, detailed distribution descriptions, watershed and fisheries management objectives, and factors contributing to potential future introductions or inhabitations of the river by non-indigenous fish. Recent collection records from the Souhegan River and its tributaries, presented in a report on the flow dependent resources of the river (NAI, 2004), provided an initial list of fish species known to occur within the Souhegan River watershed. This list was supplemented by a review of two of the primary sources on the fishes of New Hampshire and Massachusetts (Scarola, 1987; Hartel et al., 2002) to identify species that are known to occur within the waters of the Souhegan River region. Historical records or accounts were investigated to confirm the past presence of fish species believed to have been extirpated from the river (e.g. anadromous species) (Livermore and Putnam, 1888). Finally, detailed distribution information on the fishes of the Northeastern United States on a regional (Halliwell et al., 1999) and watershed scale (Schmidt, 1986; Hartel et al., 2002) were reviewed to identify missing species or mediate conflicting distribution accounts. The final list is indicative of the assortment of established fish species found within this region and reflective of the different ecoregional zones within which the Souhegan River occurs (Halliwell et al., 1999). For example, the list includes both slimy sculpin and swamp darter, species limited to the Northeastern Highlands (Upper Souhegan) and Northern Coastal Plains (Lower Souhegan) ecoregions, respectively (Omernick, 1987; Halliwell et al., 1999).

Conflicting distribution accounts led to controversy over the inclusion of some species not recorded in recent collection records within the watershed. Tessellated darter, for example, was not collected within any of the Souhegan watershed samples presented in the Instream Protected Uses and Outstanding Resources of the Souhegan River (2004) report, nor was the Merrimack River watershed considered part of its natural distribution by Scarola (1987) or Schmidt (1987). However, tessellated darter was included in the L-TFC as a result of the presence of this species in a sample from the Soucook River, a tributary of the Merrimack. It is considered native to both the Merrimack and Nashua (a tributary of the Merrimack River having a source within very near proximity to the source of the Souhegan, beginning within the Northern Highlands, and flowing through the Northeastern Coastal plains ecoregion to its confluence with the Merrimack just south of the Souhegan) Rivers by Hartel et al. (2002). Slimy sculpin was also included in the final list, despite the absence of this species from recent collection records, due to its consideration as native to and historically present within the Merrimack drainage (Schmidt, 1987; Hartel et al., 2002). Anadromous species were also considered due to the United States Fish and Wildlife Service's inclusion of the Souhegan River in their efforts to restore Atlantic salmon and American shad to the Merrimack River. Further supporting this decision was the proposed removal of the Merrimack Village Dam, which would provide anadromous fish with access to the Souhegan River and its tributaries as far upstream as Milford, New Hampshire and an historical account given in the Wilton Town History which stated that "alewives, shad and salmon penetrated as high up the river as Greenville…as late as 1773-4" (Livermore and Putnam, 1888).

The inclusion of anadromous species in the list of potential species imposes a dilemma when using Target Fish Communities to evaluate the status of fauna existing within a river. The problem is one that was acknowledged by Bain and Meixler (2000) in their initial development of a TFC when they noted that reference rivers "…were not in a natural or fully pristine state but instead were recognized as the best source for data…" relative to the study river. Accounting for proportions of anadromous species is difficult if not impossible since many have experienced range-wide extirpations or decline and no longer exist in their natural or historic proportions even within relatively un-impacted potential reference rivers. One solution would be to take the TFC method one step further through the development of a Reference Fish Community (RFC). A RFC would include all species that existed within the watershed historically but have since been extirpated (e.g. anadromous fishes), and would account for proportional differences of those species that may be currently under-represented, such as brook trout. The expected proportions of these species would be computed using expert-opinion-based ranking within the community. Development of a scientific approach to this concept may prove critical as state agencies begin to adopt TFC methodology as policy and management practices given the importance of anadromous fish restoration within this region and throughout. Such an approach could serve to improve the versatility of TFC application while providing the means necessary to identify management targets and evaluate restoration efforts. Identification of target proportions for these species may also provide guidance for the rehabilitation and management of habitats that may be critical to future recoveries or re-establishments of these populations.

Overall, the upper and lower Souhegan fish communities were similar to the respective TFC models developed for these portions of the river. However fish densities in the Upper Souhegan samples were considerably lower than in previous studies conducted using the same collection method on the Pomperaug, and Eightmile Rivers in Connecticut. In the Upper Souhegan River proportions of blacknose dace and longnose dace (fluvial specialist species) were significantly higher than expected while proportions of white sucker and common shiner (fluvial dependent species) were considerably lower. A possible reason for this may be the fragmentation of habitats created by multiple dams within the upper portion of the watershed as both of these fluvial dependent species are required to make upstream migrations to and from suitable spawning locations as juvenile and adult habitat requirements are significantly different for these species (Scarola, 1987; Hartel et al., 2000). Pollution intolerant and cold-water species (Atlantic salmon, brook trout, and slimy sculpin) were missing from the Upper Souhegan with the exception of the small proportion (1%) of stocked juvenile Atlantic salmon. Temperature measurements taken within the Souhegan River while electrofishing and by instream monitors over the past two years, and at the outflow of impoundments along the river and its tributaries revealed occurrences exceeding the thermal tolerances of these species. Pollution tolerant species were only slightly higher than target proportions indicating that thermal conditions within the upper portion of the river may be more closely related to these deviations from the U-TFC than pollution.

In the Lower Souhegan River the proportion of white sucker was considerably less than the L-TFC proportion. However, proportions of fluvial dependent species as a whole were nearly identical to target proportions. Fluvial specialist and macrohabitat generalist species guild proportions were also similar to target proportions based on these classification guilds. The only significant deviations from target conditions with regard to pollution tolerance and habitat use classification guild proportions among cold-water pollution intolerant species, both of which were underrepresented (nearly absent) in the existing fish community.

The Target Fish Communities developed for the Souhegan River were successful in their identification of community structures to serve as a reference model for the structure of the existing communities within the river. By comparing the existing community structures to these models we were able to identify deviations of individual species. Further comparisons based on the habitat uses, pollution tolerances, and thermal requirements of these species allowed us to identify possible reasons for departures from target conditions with regard to flow regime and water quality and condition. Water quality and condition appear to have a greater impact than flow conditions on the fish community structure of the Souhegan River based on the structure of these communities at the time of our survey. This report provides an assessment of the current conditions of the Souhegan River fish communities and a foundation for comparison to future evaluations of these communities and investigations into factors affecting their structures such as, instream flow, habitat, and water quality and condition.

One technical aspect that should be considered in the above comparisons is the use of observed relative abundances of fish as an estimate of existing community structure. Although this method is proposed by Bain and Meixler and used in several subsequent studies it is accompanied by considerable inaccuracy. The data collected during one fish ecological survey represents only a one small snapshot of the fish community. The representativeness of this sample strongly depends on temporal, spatial and technical issues such as number of samples, gear used for fishing, weather and past hydrological conditions. Subsequently, the community structure represented by observed relative abundances does not follow the power law distribution, as does TFC model[6]. This creates a source of mathematical error when a comparison is made between the TFC model and the existing fish community. One option to take these aspects into account is to apply the same weighted ranking routine to the sampled fish data as is used in the Target Fish Community model and consider the surveyed data for what it actually is: a sample of the exiting fish community. Similarly to the RFC concept proposed above, due to the experimental nature of this method the results presented here do not include this existing fish community model but rather follow published and widely recognized methods. However, the readers should be aware of the above caveats and consider options available for future improvements.

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[6] The underlying assumption of TFC model is that distribution of species in the community follows a power law.

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